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THE APOLLO 17 REGION: A COMPOSITIONAL OVERVIEW. R. Jaumann and G. Neukum, DLR, Institute for Planetary Exploration, Berlin/Oberpfaffenhofen, Germany.

Apollo 17 is located at a mare/highland boundary where the surface shows significant compositional heterogeneities. The composition of surface materials is estimated by analyzing their spectral/chemical correlations. Based on this spectral/chemical analysis the chemical and normative mineralogical composition of two highland units and three mare units has been estimated.

Introduction: The purpose of this investigation is to use spectral/chemical studies in order to determine the composition of Apollo 17 geologic units. The landing site itself and its surroundings are expected to expose different geologic settings ranging from basaltic materials over highland components to pyroclastic deposits [1–3]. Thus, Apollo 17 is an ideal place to study the mechanisms of mare volcanism, interaction of mare and highland materials, and pyroclastic activities. However, the understanding of such processes requires detailed knowledge about the chemical and mineralogical composition of the geologic units studied. Although the composition of the Apollo 17 landing site is known from the analysis of returned samples,

TABLE 1. Chemical composition of the materials exposed at the local surface points (Fig. 1).

Location	FeO	TiO ₂	Al ₂ O ₃	MgO
Ap17	16.8	7.9	12.9	11.0
Ap17 (L)	16.8	8.3	11.8	10.1
T5	19.8	8.9	9.8	8.8
S2	17.1	4.8	10.6	10.7
S3	17.1	7.4	11.7	11.0
S4	16.7	6.3	11.5	11.5
V2	11.2	1.0	20.6	6.3
L1	14.1	2.1	15.0	9.6
L2	14.0	2.2	14.2	11.2
σ	<1.7	<2.0	<2.5	<2.0

Ap17 (L) summarizes the results of the chemical analysis of Apollo 17 samples. All other data are derived from the spectral/chemical analysis of remotely sensed measurements. The dimension is wt% and the error (σ) indicates an upper limit for accuracy of the analysis.

only little compositional information can be provided from direct sample studies for the surrounding areas of this complex geologic structure. So far, data of the Apollo 17 Geochemical Orbiter Experiments provide information on the concentration of Fe, Ti, and radioactive elements as well as on Al/Si and Mg/Si concentration ratios [4,5]. This information, however, is restricted to low ground resolutions, which are not sufficient for detailed mineralogical analyses. On the other hand, when we consider spectroscopic measurements of the Apollo 17 area and combine these measurements with the spectral/chemical correlations of Apollo 17 samples, it is feasible to establish a compositional analysis of the Apollo 17 area that is calibrated to the spectral/chemical evidence of the Apollo 17 landing site [6].

Compositional Studies: Compositional information can be derived from an analysis of the spectral/chemical correlations of lunar surface materials. For this purpose the spectral variations of lunar samples are identified and compared with the variations of the concentration of chemical constituents [6]. Such a sample-based analysis provides parameters that can be used to interpret the spectral variations in remotely sensed spectroscopic data. By applying the technique to Apollo 17 soil samples, the concentration of some chemical key elements like Fe, Ti, Al, and Mg can be estimated from spectral measurements. When the technique is transposed to remotely

TABLE 2. Normative mineralogical composition of the materials exposed at the local surface points (Fig. 1).

Location	Ol	Px	Pl	Il
Ap17	13.8	34.1	36.5	15.6
T5	3.8	49.6	27.3	19.2
S2	8.4	50.1	30.0	11.4
S3	10.0	41.5	33.3	15.2
S4	11.2	43.1	32.5	13.2
V2	15.2	19.0	61.3	4.4
L1	13.6	35.4	44.3	6.6
L2	15.9	37.3	41.3	5.6
σ	<1.5	<2.0	<1.5	<2.0

The dimension is wt% and the error (σ) indicates an upper limit for the accuracy of the analysis. Ol = olivine, Px = pyroxene, Pl = plagioclase, Il = ilmenite.

sensed spectral data the accuracy is within 10% compared with the result of the chemical analysis of Apollo 17 samples (Table 1) or the results of the Apollo 17 Geochemical Orbiter Experiments [6]. Normative mineralogical information (Table 2) can be derived by comparing the calculated chemical concentrations with the concentration of Apollo 17 normative minerals (mineral phases of samples 74255 and 72395 [7]) [8]. Based on this approach the composition of the Apollo 17 surrounding areas can be determined relative to the ground-truth of the Apollo 17 landing site. The database consists of spectral/chemical parameters derived from the analysis of Apollo 17 soil samples, which transform spectral measurements into compositionally interpretable information, and of telescopic spectra obtained in the visible and infrared wavelength range [6,8]. The visible to near-infrared spectra (0.35–1.0 μm) are taken by using a CCD camera covering a regionally extended area, whereas the infrared spectra (0.7–2.5 μm) are taken at local surface points (Fig. 1) by using a CVF spectrometer. The ground resolution of the spectral measurements is 1–2 km. When the characteristics of spectra taken at the local surface points (Fig. 1) are used as end members, the distribution of compositional units can be estimated from the areally extended CCD spectral measurements.

Geological Interpretation: The geological interpretation of surface units is based on the chemical (Table 1) and mineralogical (Table 2) results, as well as on photogeological studies. Due to this interpretation, five geological units are identified (Fig. 1).

(1) Anorthositic highland materials (a) constitute an Al-rich unit that has an Fe/Al ratio < 0.6 and is characterized by its high content of plagioclase. The anorthositic highland materials are defined spectrally and chemically at the surface point V2 (Fig. 1). The unit is distributed in the form of small patches north and south of Apollo 17. Photogeological studies [1] indicate a pre-Nectarian age. (2) Mafic highland materials (n) are relatively Al-rich, but with an Fe/Al ratio ≈ 1 and a significant pyroxene component indicating the mafic characteristics of the unit. In terms of highland rocks these materials are comparable with gabbros (norites). The spectral/chemical reference for this unit is defined at the surface points L1 and L2 (Fig. 1).

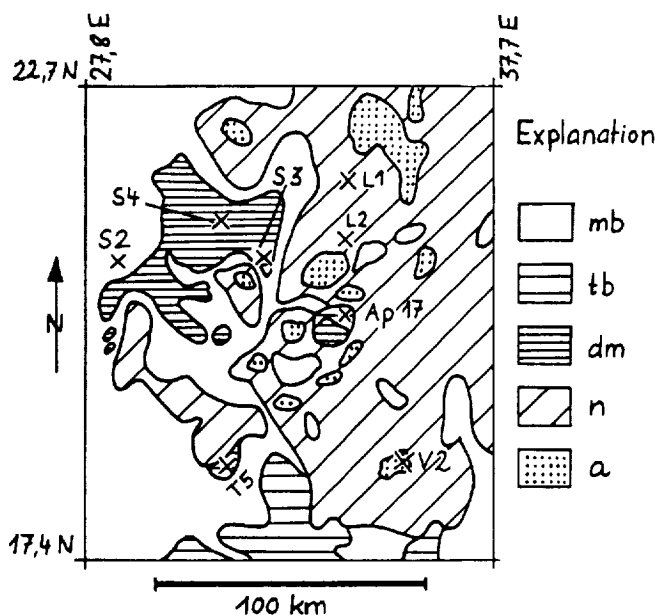


Fig. 1. Geologic map of the Apollo 17 area. (X) indicates the position of local surface points. For detailed description of the units see text.

The mafic materials dominate the highlands surrounding Apollo 17. The age is assumed to be pre-Nectarian to Nectarian. The mare units of the Apollo 17 region are attributed to the Imbrian system [1,2]. In general, basalts are classified by their titanium content. Based on the TiO_2 concentrations normal mare basalts ($\text{TiO}_2 < 5 \text{ wt\%}$) can be distinguished from titanium basalts ($\text{TiO}_2 > 5 \text{ wt\%}$). (3) The spectral/chemical characteristics of a typical mare basalt (mb) as exposed at the surface point S2 (Fig. 1) can be compared with the characteristics of a pigeonite basalt defined by a relatively enriched pyroxene component. Mare basalts dominate the southwestern part of the mare/highland boundary between Mare Serenitatis and the Taurus Littrow mountains and also fill the valleys west of Apollo 17. (4) Titanium basalts (tb) as exposed at the surface points Ap17 and T5 (Fig. 1) are characterized by high TiO_2 concentrations and thus by a high ilmenite content. Titanium basalts are mainly exposed at Apollo 17 and south of the landing site toward Mare Tranquillitatis. (5) The materials exposed on the Mare Serenitatis shelf area west to the Apollo 17 landing site (S3 and S4 in Fig. 1) exhibit a spectral/chemical characteristic similar to that of the titanium basalts. However, this unit shows a fine texture, is smoother than the titanium basalt unit, and is enriched in the agglutinate and glass component [3]. The photogeologic interpretation indicates that this unit is mainly composed of pyroclastic materials (dm). The present study shows that the investigation of spectral properties is a useful tool to interpret the composition of lunar surface materials.

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NEOKREEP: A NEW LUNAR COMPONENT AT APOLLO 17.
 Eric A. Jerde, Gregory A. Snyder, and Lawrence A. Taylor, Department of Geological Sciences, University of Tennessee, Knoxville TN 37996, USA.

Introduction: The Apollo 11 (Mare Tranquillitatis) and Apollo 17 (Mare Serenitatis) landing sites are important as the only sources of high-Ti basalt visited by the Apollo missions. The lunar high-Ti basalts ($> 6\% \text{ TiO}_2$; [1]) have no volumetrically comparable analogues among terrestrial basalts and require the presence of ilmenite in the source region, probably representing cumulates produced late in the crystallization of the lunar magma ocean [2].

Six principal groups of high-Ti basalts have been described, three from each of the two sites (see the review by [1]). The three groups of high-Ti basalts at the Apollo 17 site (termed "types") are all low-K ($< 2000 \text{ ppm K}$). These types are A, B, and C, with the type B basalts recently subdivided into varieties 1 and 2 (Fig. 1). It was shown by Neal et al. [3] that the type A basalts and both type B varieties can be generated through fractionation of observed phenocryst phases from a single magma. An evaluation of isotopic data [4] indicates an age of $3.75 \pm 0.02 \text{ Ga}$ for the type A basalts and $3.69 \pm 0.02 \text{ Ga}$ for the type B1/B2 basalts. The scarce type C basalts (only six examples) from Apollo 17 are more primitive than types A and B, having elevated MgO and Cr contents. However, the REE and alkali element (e.g., Rb) abundances in type C basalts are elevated relative to the type B basalts [5]. Neal et al. [5] suggest that the parent to the type C basalts was metasomatized by an alkali-rich fluid. Only two type C samples have been dated, yielding ages ranging from 3.63 ± 0.14 to $3.75 \pm 0.08 \text{ Ga}$.